CERTIFICATION

On this day, this ninth day of July, 2004, I, John F. Sanders personally certify that:

1. I am well-qualified as a translator of German to English and am employed as such by Kenyon & Kenyon (One Broadway, New York, New York 10004); and

2. I have carefully made the attached English language translation from the original German document entitled

Fokalfläche und Detektor für optoelektronische Bildaufnahmesysteme, Herstellungsverfahren und optoelektronisches Bildaufnahmesystem

[FOCAL SUFACE AND DETECTOR FOR OPTOELECTRONIC IMAGE-RECORDING SYSTEMS, MANUFACTURING METHOD AND OPTOELECTRONIC IMAGE-RECORDING SYSTEM]

and

3. The attached translation is an accurate English version of such original to the best of my knowledge and belief.

JOHN F. SANDERS

Certified Translation of Original Application

Focal surface and detector for optoelectronic image-recording systems, manufacturing method and optoelectronic image-recording system

The present invention relates to a focal surface for optoelectronic image-recording systems as set forth in the main subject of patent claim 1, a method for manufacturing a focal according to the definition of the species in patent claim 9, a method for manufacturing according to the definition of the species in patent claim 11, a detector according to the definition of the species in patent claim 17 and an optoelectronic image-recording system according to the definition of the species in patent claim 20.

Optoelectronic image-recording systems are used, for example, in the field of space travel, for monitoring the earth, in reconnaissance systems or in automotive engineering for recognizing obstacles. In the sensor head, optoelectronic image-recording systems consist of front optics, for example an objective or a telescope, detectors in the focal plane and electronics. The front optics, reflecting telescopes as often used for space instruments, for example, have a curved field of view or a curved focal plane. However, the detector technology requires a planar design. To flatten the image surface, so-called field correctors or field flatteners must, therefore, be connected optically downstream of the telescopes or optics in order to be able to place planar detector surfaces into the focal plane. In general, the field correctors consist of lens assemblies that can typically effect a correction of the field of view only in a limited region of the visual field.

For illustration purposes, Figure 4 shows a known Cassegrain system that can be used as a reflecting telescope for space instruments. Figure 5 shows the curved

focal surface of a concave mirror. Figure 6 shows a Quasi-Ritchey-Chrétien booster system with a known field corrector and its beam paths.

However, in many applications, a broad visual field is required, for example to achieve a scanning band that is as broad as possible. A corresponding expansion of the visual field of the telescope is particularly required in a scanning pushbroom instrument. For reasons of stability, particularly to withstand the starting loads, reflecting telescopes are primarily used for geometric high-resolution space instruments. Furthermore, in many cases a broadband spectral sensitivity is required.

The detectors in the focal plane are the hearts of optoelectronic image-recording systems. For example, known CCD detectors are used, or else the known CMOS detectors with active pixel technology. These detectors have integrated readout electronics and can be manufactured in one manufacturing process.

In the field of automotive engineering, cameras having a large visual field or panorama cameras are required for recognizing obstacles. However, they require complicated optics to achieve a large visual field and to reduce distortions. Correspondingly, the price for a camera or an image-recording system for such applications is very high.

To achieve a high image quality, very narrow thermo-mechanical tolerances are required as well. The field correctors often restrict the spectral transmission range, which is caused, for example, by the narrow transmission range of the employed lens glasses.

Overall, the known optoelectronic image-recording systems or detector set-ups exhibit significant disadvantages, such as the restriction of the visual field and the limitations of spectral transmission properties of the telescopes, a complex design having field correctors to create planar image planes, complicated and elaborate front optics and high costs.

It is, therefore, the objective of the present invention to overcome the aforementioned disadvantages, to simplify optoelectronic image-recording systems and to enable wider visual fields.

This objective is accomplished by the focal surface for optoelectronic image-recording systems as set forth in patent claim 1, the method for manufacturing a focal surface as set forth in patent claim 9, the method for manufacturing a detector as set forth in patent claim 11, the detector for image recording as set forth in patent claim 17 and the optoelectronic image-recording system as set forth in patent claim 20. Additional advantageous features, aspects and details of the invention are derived from the dependent claims, the description and the drawings.

According to the present invention, a focal surface for optoelectronic image-recording systems is created, using an arrangement of detectors for image recording and a detector carrier for holding the detector, whereby each detector is made of at least one silicon element that is bonded to a flexible carrier substrate, and whereby the focal surface and/or the detectors exhibit a curvature for recording a curved field of view. This renders field correctors for the creation of planar image planes unnecessary, thus simplifying the front optics of the image-recording system. They can be made thermo-mechanically more robust. Additional visual fields become possible, that may be at 15° in the case of a Schmidt telescope, for example, because there are no more field correctors that would otherwise limit the visual field. Furthermore, broadband spectral transmission properties of the telescopes or front optics are retained.

The detectors are preferably made of thinned silicon wafers and arranged in a curved manner at the focal surface. Particularly, the detectors are made using an auxiliary carrier that is bonded with the silicon element for the thinning of the silicon element, and that can be or is removed after the thinning. In this manner, the silicon element, or the detector, can be made especially thin and flexible, such that

a suitably large curvature can be achieved. The result is a particularly great flexibility or bendability of the detectors and of the focal surface.

Preferably, the silicon element or elements have a thickness in a range of up to a maximum of about 20 μm, and especially, preferably in a range of about 10 μm or less. The detectors may be flexible and particularly designed as CMOS line detectors. In this manner, flexible and curved or curvable detectors with integrated readout electronics can be made in a cost-effective manner, using CMOS technology.

Preferably, the focal surface includes an actuator for variable curving of the detectors or of the focal surface. This enables an active control of the flexible, curved focal planes. New telescope concepts can be implemented that exhibit improved optical qualities, are simpler in design or have fewer components.

In particular, the focal surface can be equipped with a temperature control system to keep the detectors within a defined temperature range. For this purpose, the detector carrier may include channels for a cooling medium or may be coupled to Peltier elements. This reduces the sensitivity to temperature fluctuations, that is, the focal surface and image-recording systems equipped with such a focal surface are thermo-mechanically more robust.

For the method of the invention for manufacturing a focal surface for optoelectronic image-recording systems, a detector carrier is provided with a detector arrangement for image recording, whereby, in each instance, at least one silicon element is connected with a flexible carrier substrate for forming flexible detectors, and whereby the detector carrier exhibits a curvature and the flexible detectors are adapted to the curvature of the detector carrier. This method enables the creation of focal surfaces that do not require field correctors when employed in optoelectronic image-recording systems. The method can be carried out in a cost-effective manner employing micro-mechanic technology. The method forms the basis for

creating optoelectronic image-recording systems or focal surfaces that allow larger visual fields, improved optical properties and a simplified design. Furthermore, the optical elements such as lenses, telescopes, etc. can be made simpler and with a reduced weight.

Preferably, the silicon element is thinned when using the method of the invention.

According to an additional aspect of the invention, a method for manufacturing a detector for optoelectronic image-recording systems is provided, where at least one silicon element is thinned and bonded to a flexible carrier substrate, such that it has a flexible structure and can be adapted to the curvature of a field of view. With the method of the invention, it is possible to create flexible detectors or detectors that are curved or can be curved and allow use in focal surfaces and in optoelectronic image-recording systems without the need for field correctors. Furthermore, the advantages already mentioned above can be realized as well.

Advantageously, the following, additional method steps can be carried out in the method of the invention for manufacturing a focal surface, and in the method of the invention for manufacturing a detector:

For thinning the silicon element, the element can be bonded to an auxiliary carrier, whereby the auxiliary carrier is or can be removed after thinning, for example. In this manner, the thickness of the silicon elements can be greatly reduced and their flexibility greatly increased, resulting in a low number of rejects.

The thinning or the reduction of the thickness of the silicon element can be achieved by removal, for example through grinding, etching, spin etching, chemical mechanical polishing (CMP), or a combination of these. Depending on the application, it is possible to achieve high removal rates, e.g., with grinding, medium removal rates, e.g., with spin etching, or a very high precision, such as with the CMP method.

Advantageously, with these methods, the silicon element is initially present as a wafer, where the wafer is thereafter or later split into chips, preferably prior to being bonded to the carrier substrate. This enables a very cost-effective production.

The silicon elements are advantageously provided with electrical contacts, using isoplanar contacting technology. This even allows extremely thin chips to be contacted without the risk of destroying the chip, because no high, local compressive forces are present, as is the case with bond dies for example.

Preferably, the silicon element is provided with a transparent coating that distinctly reduces the sensitivity to breaking.

According to yet another aspect of the invention, a detector for image recording that is made of a silicon element is created, whereby the silicon element is thinned and bonded to a flexible carrier substrate, and whereby the detector is flexible. With the detector of the invention, it is possible to create focal surfaces for image-recording systems that can be structured in a curved manner, such that corresponding image-recording systems do not require field correctors. In this manner, the above mentioned advantages can be achieved.

Advantageously, the silicon element has a thickness in the range of less than 50 μm, preferably less than 20 μm and in particular about 10 to 20 μm. The length/width ratio of the silicon element can be in the range of approximately 20 to 60, preferably about 40. It is advantageous when it is greater than 20.

The detector is preferably made, using a method of the invention as described above.

Finally, an optoelectronic image-recording system is created by the present invention, having front optics for recording the image, and a detector set-up that is ar-

ranged in a focal surface of the front optics assembly, whereby the detector set-up is arranged in a curved manner in the focal surface. This allows additional visual fields, whereby, in particular, the optics can be simplified.

Field correctors are no longer required. Further advantages are attained as well, such as those that have been mentioned above in connection with the focal surface of the invention and the detector of the invention.

In particular, the optoelectronic image-recording system includes a focal surface of the invention and/or a detector of the invention.

In the following, the invention is exemplarily described on the basis of the drawings, which show,

Fig. 1	a schematic sectional view of a focal surface as the preferred embodiment of the invention;
Fig. 2	the curvature of a field of view to which the focal surface is adapted;
Fig. 3	a top view of a detector module or detector element of the invention;
Fig. 4	a known Cassegrain system;
Fig. 5	a curved focal surface of a concave mirror;
Fig. 6	the beam path in a known Schmidt telescope having a reflective corrector;
Fig. 7	a longitudinal section of a focal surface having a temperature control system according to an additional preferred embodiment of the invention;
Fig. 8	a longitudinal section of a focal surface having a temperature control system according to another preferred embodiment of the invention;
Figs. 9a to g	various steps for manufacturing the focal surface of the invention; and
Fig. 10	a focal surface of the invention, having a variable curvature radius.

A first preferred embodiment of the invention is described in the following, using Figure 1. Figure 1 shows a schematic section view of a portion of a focal surface 10. The focal surface 10 includes one or more detectors 11, whereby only one detector 11 in the form of a line sensor is shown in the drawing. The detector 11 is a CMOS line detector with a relatively large length/width ratio that is about 40 in the present case. It consists of a chip or a silicon element that is bonded to a flexible carrier substrate 13 via a first bonding layer 12. The first bonding layer 12 is an adhesive coating that is particularly thin and exhibits a thickness of less than 10 μm, preferably of about 1 to 2 μm. The carrier substrate 13 is made of a flexible foil with a thickness of about 50 to 100 μm. The flexible carrier substrate 13 with the chip on it is bonded to a detector carrier 15 by a second bonding layer 14 that is an adhesive coating as well. Thus, the detector carrier 15 forms a focal surface backplate for carrying numerous detector modules or elements with detectors 11. At its surface 15a, the detector carrier 15 exhibits a curvature to which the detector 11 is adapted. That is, the detector 11 is also curved and flexible. Due to its curvature at its surface 11a, the detector 11, together with additional detectors that are present on the detector carrier 15, is suitable for recording a curved field of view.

The degree of curvature of the focal plane depends on the specific application. For a known wide-angle telescope or a typical reflective Schmidt telescope in an image-recording system, an aperture diameter Do of, for example, 20 cm and a focal length f of 1 m can be assumed. The aperture ratio F# is, therefore: F# = f/Do = 5. Different image heights and the defocus can be calculated as a function of the field viewing angle. For example, a field viewing angle of $\pm$ 3° results in an image height of 105.52 mm. At $\pm$ 3°, the height differences are -1.2 mm compared to the center and at $\pm$ 6°, 5.35mm. The corresponding curvatures can be obtained with the detectors 11 or focal surface 10 of the invention.

The curvature of the focal surface 10 is designed such that the wave front strikes the detectors 11 or the detector surface 11a perpendicularly. The required tolerances result from the depth of field δS given by the following equation:

$$\delta S = \frac{\pm \lambda}{2\, n \sin^2 U_m}$$

by observing the quarter-wave limit, whereby U_m is the limiting beam angle and λ is the wavelength.

With $n = 1$, $\lambda = 0.65\ \mu m$ and F# = 5, the resultant value for the physical depth of field δS is $\pm$ 32.5 μm. Tolerances in the range of about 30 μm can be maintained without a problem when manufacturing focal surface 10. The curvature of the focal surface 10 according to the preferred embodiment is shown in Fig 2. There, the defocus in mm is plotted as a function of the opening angle in degrees, whereby the focal surface is adapted to this curve.

Figure 3 shows schematically a top view of the detector module or line module with the detector 11 and the flexible carrier substrate 13. The surface 13a of the carrier substrate includes electrical contacts 16 as exterior connectors for the electrical connection to control and readout electronics. The electrical contacts 16 are located on the edge along the width of the detector module. Electrical connections 17 from the chip or the detector 11 to the carrier substrate 13 are pulled across the chip edge. Thus, the contacts are made by the isoplanar contacting method such that no high, local compressive forces act on the extremely thin chips during the manufacturing process, such as is the case with wire bonding, for example. The electrical connections 17 are formed by screen-printing.

CMOS-APS line detectors are used as detectors 11 in the preferred embodiment of the invention. However, it is also possible to use CCD detectors. The detector lines may have 10,240; 8,192; 6,144; 4,096; 2,048 or 1,024 pixels. The length of the used line detectors or silicon components is about 100 mm, while the width is only about 3 mm, which results in the very large length/width ratio. The silicon elements or silicon wafers that form the detectors 11 are thinned or reduced in

their thickness to about 25 μm. The thickness of the detector 11 or of the actual line sensor that is supported by the carrier substrate 13 is about 20 μm.

The line sensor or detector 11 with its approximately 2,000 to 10,000 pixels includes also a transparent coating that is not shown in Figure 1. For this purpose, the corresponding CMOS line is laminated between two foils, whereby the lower foil forms the carrier substrate 13 with the described connection structures, while the upper foil is transparent and is only used for protection purposes. This significantly simplifies the subsequent handling of the line module or the detector line on the flexible carrier substrate 13, and the sensitivity to breaking is significantly reduced for the thinned silicon chip that is formed as a monocrystal.

Figure 4 shows a known Cassegrain system as an example for front optics that can be equipped with the curved focal surface according to the present invention in order to form an optoelectronic image-recording system. With the Cassegrain system as front optics 20, the beams of a distant object strike a concave mirror 21 and are reflected into a focal point f1. Before the beams converge a convex mirror 22 reflects the beams into a second focal point f2 through a central opening 23 in mirror 21. In the classic Cassegrain form, the mirror 21 is a paraboloid and the convex mirror 22 is a hyperboloid having the focal points f1 and f2. Other known designs of front optics together with the curved focal surfaces of the invention are possible as well, such as the Schmidt system or the so-called Ritchey-Chrétien system.

In general, converging elements or concave mirrors have a strong Petzval curvature, which is convex in the direction of the incident beams and is shown in Figure 5. In general, the Petzval curvature of a reflecting surface is calculated using the equation

$$P = 2nc$$

where n is the refractive index of the medium that is in contact with the mirror and c = 1/r is the curvature parameter.

Fig. 6 shows as an example the beam path in a Schmidt telescope with a reflective corrector 24 according to the related art. Additionally, the telescope includes a primary mirror 24b and a folding mirror 24c. The reflective corrector 24 is used to allow an image to be formed on a flat focal surface or a focal plane 24a. Other known systems may use transmissive correctors or corrector plates, for example, to reproduce the beams onto a flat surface as is demanded by the known detector technology.

In its place, the image-recording system according to the present invention includes a curved focal surface, for example according to the design described above, that is coupled to known front optics 20 and that is adapted to the curvature of the beams or the field curvature.

Fig. 7 shows a curved focal surface 50 according to another exemplary embodiment. The structure of the detector module consisting of a detector 11, the carrier substrate 13 and the two adhesive layers or bonding layers 12, 14 is designed in the same manner as the exemplary embodiment described above with reference to Figure 1. However, the channels 51 are integrated in the detector carrier 15 or in the backplate of the focal surface, where said channels are designed as micro-channels or micro heat pipes. The arrangement of the channels 51 is such that the temperature distribution in the backplate or in the detector carrier 15 is as uniform as possible. To this end, channels 51 run in counter-current directions, that is, a bi-directional flow of the cooling medium is achieved in the detector carrier 15 or in the channels 51.

Figure 8 shows another variant of the implementation of a temperature control system in a focal surface 60. Here, Peltier elements 61 are coupled to the backside of the detector carrier 15. To this end, 3 to 10 Peltier elements, for example, can be

installed at the backplate, such that a uniform temperature distribution is ensured, even under a very non-uniform distribution of the heat dissipation. This arrangement has the advantage that control is by electronic means, thus avoiding the need for pumps, for example. Furthermore, an otherwise necessary heat discharge to the environment, as well as the sealing of cooling circuits, is avoided as well.

Temperature control is carried out by calculation programs, taking into account temperature-dependent material properties. The additional structure on the detector carrier 15 is analogous to the one described above with reference to Figures 1 and 7.

The focal surfaces 50 and 60 with a temperature control system according to Figures 7 and 8 are coupled, for example, to a Schmidt telescope as front optics 20. Due to the high flexibility of the detectors 11, it is also possible to provide the curved detector lines with a variable or adjustable curvature radius.

The temperature control system is designed such that all pixels of the line sensor in the curved structure can be maintained within a defined temperature range, even under extreme external conditions such as extreme environmental temperatures or extreme light incidence across the line. For example, for the bonding layers 12 and 14 flexible pyrolitic graphite foils with coefficients of thermal conductivity of up to 600 to 800 W/mK at a thickness of 0.1 mm and a density of 1 g/cm^3 can be used as materials. Furthermore, encapsulated foils that have on the inside a TPG material (thermal pyrolitic graphite) with a very high coefficient of thermal conductivity of 1200 W/mK and have on the outside various potential materials such as copper, aluminum, carbon fiber or Al-SiC can also be used for the detector structure.

In the following, a method of the invention for manufacturing detectors or thin line detectors and a curved focal surface 10, 50, 60 is described in view of Figures 9a to 9g.

First, silicon components or chips are provided that have a length of about 100 mm and a width of about 3 mm. Then, the finished, processed Si wafers are thinned to a thickness on the order of 25 μm, that is, their thickness is reduced. To this end, a wafer or silicon element 71 to be thinned is bonded to an auxiliary carrier 72. In the bonded condition, the active side 71a of the Si element 71 faces the auxiliary carrier 72 (Fig. 9a). The auxiliary carrier 72 can be a silicon or a glass wafer. An adhesive applied in liquid form or an adhesive film is used as the interim layer 73 between the silicon element 71 and the auxiliary carrier 72. Strict attention is paid that the bond is without shrink holes. The subsequent thinning process is attuned to the topography of the wafers to be thinned. Since the line detectors are very long, e.g., 100 mm, particular attention is paid to the thickness variation and a potential wedge error in the evolution of the thinning process. Both, the thickness variation and the wedge error should each be $\leq$ 1 to 2 μm.

The actual thinning of the approximately 700 μm thick wafer is accomplished in a multi-step process from grinding to spin etching to chemical mechanical polishing (CMP). The grinding process has a very high removal rate that may be 100 to 200 μm/min, for example. However, grinding may cause defects in the crystal surface of the silicon. This is avoided with spin etching at a medium removal rate of 20 to 50 μm/min, however the result is mostly a slight waviness. CMP, on the other hand, has a very low removal rate in a range of 1 to 2 μm/min but offers the highest precision. The thinning process is carried out by using the most suitable process, such that the required specifications are attained with a justifiable expenditure in time.

The auxiliary carrier 72 is kept until the line detector is placed on the carrier substrate 13 (Figure 9b). This offers the advantage of easier handling. The silicon

element 71 is in contact with the auxiliary carrier 72 with its active side 71a. The silicon element 71 or the wafer is thinned to a thickness of less than 50 μm.

The splitting of the wafers into chips can be carried out either before or after thinning. In the present case, the standard splitting procedure of sawing is not employed because, in the case of thinned wafers, it carries the risk of chipping the edges of the chip. Under certain conditions, the notch effect might fracture the chip, which is particularly critical in the present case due to the large length/width ratio of about 40. Thus, a splitting method is preferred that leads to clean, undamaged chip edges and yields a high amount of CMOS detector lines per wafer.

When the splitting is carried out before thinning, the individual chips are separated through trenches in the unthinned wafer, whereby the depth of the trenches corresponds to the desired remaining thickness of about 25 μm. Potential methods to create the trenches include etching methods that create vertical walls in the silicon, or sawing. Undercutting that attacks the bond pads is to be observed as a critical point in both methods. It occurs during spin etching or the CMP during the thinning process, as soon as the trenches lay open.

Although the etching method is more involved and requires an etching template and lithographic steps, it has the advantage of a more accurate and more uniform definition of the trench depth. Chipped edges that are caused by sawing prior to the thinning can still be cured during the thinning process.

Methods that permit clean chip edges, such as etching, come into consideration for splitting after the thinning. Here, one problem is the recognition of the sawing lane, since the thinned wafer points towards the carrier or auxiliary carrier 72 with its active side 71a. A solution that offers itself is to use a mask aligner with an IR alignment, to use an auxiliary carrier 72 made of glass and to use a transparent interim coating 73 (double side mask aligner) or to introduce alignment marks prior to thinning. Laser cutting may also be used for splitting as alternative to etching.

The carrier wafer is diced using a standard sawing procedure for the subsequent mounting of the thinned chips onto substrates or the carrier substrate 13.

Figure 9a shows the auxiliary carrier 72 with the bonding or interim layers 73 present on it and the wafer or silicon element 71 to be thinned. The silicon element 71 faces the auxiliary carrier 72 with its active side 71a. The silicon element 71 is thinned in this laminate as described above.

Now, the thin CMOS line detectors or silicon elements 71 with the auxiliary carrier 72 are mounted on flexible substrates 13. Figure 9b shows the laminate of auxiliary carrier 72, bonding or interim layer 73 and line detector or detector mounted on the carrier substrate 13. This laminate is bonded to the carrier substrate 13 by using an adhesive coating or a bonding layer 12 (see also Figure 1).

When mounting the thin chips, a uniformly thin, reproducible adhesive coating is applied and thereafter the long chip is placed onto the carrier substrate 13 in a plane-parallel configuration. This creates a uniformly thin, low-stress bonding joint with a thickness of less than 10 μm, preferably of 1 to 2 μm.

Now, the auxiliary carrier 72 or the carrier chip together with the bonding or interim layer 73 is removed, leaving no residue. It must be ensured that no residue remains and that no chemical reaction occurs with the metallic pad coating.

Flexible foils that later allow for the mounting in a curved surface of a FP backplate or a focal surface backplate are used as carrier substrates 13.

In certain cases, as an alternative to the construction via a flexible foil as an interim carrier, the line detector may also be mounted directly, that is, without auxiliary carrier, onto the FPA carrier or focal surface carrier.

Figure 9c shows schematically, as a sectional view, the carrier substrate 13 with the line detector 11 present on it and its electrical contacts 16a. The auxiliary carrier 72 (Figure 9b) is already removed.

The attachment of the contacts is carried out in the next step. Isoplanar contacting is carried out for this purpose. In comparison to the wire-bonding process otherwise typical in microelectronics, this has the advantage that no high, local compressive forces of a bonding die can lead to the destruction of the extremely thin chip.

With isoplanar contacting, the electrical connections of the chip or chip connections or contacts 16a to the substrate are pulled over the chip edge. Figures 9d and 9e show a sectional view and a top view of a schematic for the isoplanar contacting of the detector 11. The detector line or the detector 11 is mounted on the carrier substrate 13, which is a substrate foil, by the bonding layer 12, which is an adhesive. The electrical contacts 16 or the external contacts are located in an edge section of the carrier substrate 13. Electrical connectors 17 lead from the chip to the substrate across the chip edge (see also Fig. 3).

The electrical connections 17 can be established, using screen printing technology for example.

In an optionally possible test method, substrates and wafers are designed and manufactured that contain passive test structures such as Kelvin or Daisy-chain structures. The contacts are printed by varying and optimizing electrically conducting pastes. Thereafter, the resistance of the contact is analyzed for a reliable contact from the CMOS line detector to the substrate. Additional analysis is performed with regard to the influence of the chip edge on the insulation resistance, the printability, breaks in the conductors due to temperature influences, etc.

Then, the detector 11 with the structures bonded to it is provided with a transparent coating 74. To this end, the CMOS line is laminated between two foils. Figures 9f and 9g show the detector 11 with the carrier substrate 13 located underneath it and the transparent coating 74 located on the top side of the detector 11. The carrier substrate 13 is formed by a bottom foil or carrier foil, on which the connection structures are present. The cover 74 is a top foil that is transparent and serves protective purposes. This significantly simplifies the subsequent handling of the line module that is formed by the detector line or the detector 11 on the flexible substrate 13. The electrical connections 17 and external connections or electrical contacts 16 have already been described above.

Figure 10 shows an arrangement for establishing differing curvature radii in a detector 11 or detector element for optoelectronic image-recording systems that has been made according to the method described above. With this method, the detector module that consists of the detector 11, the bonding layer 12 and the carrier substrate 13 is supported from the rear side in its edge sections by support elements 75, while, from the opposite side, the force F is basically applied in the center of the detector 11, by an actuator. It is also possible, for example, to provide the detector carrier 15 (Figure 1) with means or actuators for adjusting the curvature of its surface 15a. The flexible detector 11 subject to the present invention can be adapted to the various curvatures and thus, the entire focal surface 10 with the detector 11 can be adapted in accordance with the specific requirements of the optics and the environmental conditions.

In Figure 10, the arrangement is designed as a test structure for testing curved or bendable detectors 11. During the test, the signals from the shift register of the detector 11 are read out, the functionality of the line modules verified and analyzed for potential errors, while the curvature radius of the line module is varied.

After the optional test, the line module, that is, the detector 11 that is mounted to the carrier substrate 13, is placed into the carrier 15 for the focal surface or detec-

tor. This line module must be assembled exactly. The line or detector module that is mounted to the detector carrier 15 is shown in Figure 1 and has already been described above. When fitting the detector module and adapting it to the curvature of the detector carrier 15, the specific requirements such as lateral and vertical tolerances, reliability with regard to temperature, acceleration, etc., light resistance, and the like are observed. With regard to adhering to the curvature radius, deviations of about 30 μm are permissible as tolerances, as has been shown above. These tolerances can be easily observed, because the individual thicknesses of the various layers of the line module are within the μm range (detector line about 20 μm, substrate foil or carrier substrate 13 about 50 to 100 μm, adhesive layer < 10 μm).

After inserting the line module into the detector carrier 15, the electrical connections to the control and read out electronics are established. For this purpose, a reliable mechanical and electrical attachment of the connection element on the line module is provided.

Such a complete FPA module, that is, a detector module connected to the detector carrier 15, is tested for its functionality, using appropriate tests. The reliability is incrementally increased by varying the test parameters. Especially taken into consideration are conditions that are encountered in the field of space travel, such as vibrations, accelerations, temperature, temperature gradients, temperature changes, humidity, irradiation or the effect of light, etc. The modules are incrementally optimized according to their respective requirements and operating conditions.

Using the invention and, in particular, the construction technique of curved focal surfaces according to the invention, optical instruments, especially space instruments with a broad visual field and large focal lengths are simplified. Also, in other fields of application, the front optics of an optical system can be designed signifi-

cantly simpler, because the invention allows the requirement for a planar reproduction onto the semi-conductor detectors to be avoided.

Field correctors can be avoided, which enables the creation of new telescope designs as well as instrument designs with an active or adaptive control of the shape of the focal plane that can be employed in place or in combination with the active or adaptive optics that have been employed thus far.

Front optics such as telescopes or objectives can be implemented more easily, especially for wide visual fields of reflective telescopes. An image-recording system of the invention with the focal surface described here has a lower thermo-mechanical sensitivity, i.e. a greater robustness than conventional systems. The results are lower transmission losses and a very broad-banded spectral transmission range. Active or adaptive control of the telescope optics can be complemented by methods that change the position of the detectors in the optical incident direction, for example. A further result is more cost-effective image recording system, because in the case of a greater visual field and reduced distortions, the optics can be significantly simplified.

Reference characters

10	focal surface
11	detector
11a	surface of the detector
12	1st bonding layer
13	carrier substrate
13a	surface of the carrier substrate
14	2nd bonding layer
15	detector carrier
15a	surface of the detector carrier
16	electrical contacts
16a	electrical contacts
17	electrical connections
20	front optics
21	concave mirror
22	convex mirror
23	central opening
24	corrector (SdT)
24a	planar focal surface (SdT)
24b	primary mirror
24c	folding mirror
50	focal surface
51	channels
60	focal surface
61	Peltier elements
71	Si elements
71a	active side of the Si element
72	auxiliary carrier
73	interim layer
74	transparent coating

75	support element
F	force
f_1	focal point
f_2	focal point

Patent Claims

1. Focal surface for optoelectronic image-recording systems with an arrangement of detectors (11) for image recording and a detector carrier (15) for holding the detectors (11),
whereby the detectors (11) are each made of a least one silicon element (71), and
whereby the focal surface (10; 50; 60) and/or the detectors (11) exhibit a curvature for recording a curved field of view,
characterized in that,
the detectors (11) have a flexible design,
whereby the silicon element (71) is thinned and is bonded to a flexible carrier substrate (13).

2. Focal surface as set forth in claim 1, characterized in that the detectors (11) are made of thinned silicon wafers and are arranged in the focal surface (10; 50; 60) in a curved manner.

3. Focal surface as set forth in claim 1 or 2, characterized in that the detectors (11) are made by using an auxiliary carrier (72) that is bonded to the silicon element (71) for the purpose of thinning the at least one silicon element (71) and that is removable or is removed after the thinning procedure.

4. Focal surface as set forth in one of the previous claims, characterized in that the silicon element (71) exhibits a maximum thickness of approximately 20 μm, preferably a thickness in a range of approximately 10 μm or less.

5. Focal surface as set forth in one of the previous claims, characterized in that the detectors (11) are flexible.

6. Focal surface as set forth in one of the previous claims, characterized in that the detectors (11) are CMOS line detectors.

7. Focal surface as set forth in one of the previous claims, characterized by an actuator for variably bending the detectors (11) or the focal surface (10; 50; 60).

8. Focal surface as set forth in one of the previous claims, characterized by a temperature control system (51; 61) for keeping the detectors (11) within a defined temperature range, whereby the detector carrier (15) includes channels (51) and/or is coupled to Peltier elements (61).

9. Method for manufacturing a focal surface for optoelectronic image-recording systems, where a curved detector carrier (15) is provided with a detector arrangement (11) for image recording, characterized in that, to form flexible detectors (11), at least one silicon element (71) is thinned and bonded to a flexible carrier substrate (13), whereby the flexible detectors (11) are adapted or can be adapted to the curvature of the detector carrier (15).

10. Method as set forth in claim 9, characterized in that the silicon element (71) is bonded to an auxiliary carrier (72) for the purpose of thinning.

11. Method for manufacturing a detector for optoelectronic image-recording systems, characterized in that at least one silicon element (71) is thinned and is bonded to a flexible carrier substrate (13), such that it is formed in a flexible manner and/or is adaptable to a curvature of a field of view.

12. Method as set forth in one of the claims 9 to 11, characterized in that the silicon element (71) is bonded to an auxiliary carrier (72) for the purpose of

thinning, whereby the auxiliary carrier (72) is removed or can be removed after the thinning procedure.

13. Method as set forth in one of the claims 10 to 12, characterized in that the thinning is carried out by way of removal, using grinding, etching, spin etching, chemical mechanical polishing or a combination thereof.

14. Method as set forth in one of the claims 8 to 13, characterized in that the silicon element (71) is initially present in the form of a wafer and is split into chips prior to bonding with the carrier substrate (13).

15. Method as set forth in one of the claims 8 to 14, characterized in that the silicon element (71) is provided with electrical contacts (16, 16a) by using isoplanar contacting.

16. Method as set forth in one of the claims 8 to 15, characterized in that the silicon element (71) is provided with a transparent coating (74).

17. Detector for image recording that is made of a silicon element (71), characterized in that the silicon element (71) is thinned and bonded to a flexible carrier substrate (13), and in that the detector (11) is flexible.

18. Detector as set forth in claim 17, characterized in that the silicon element (71) exhibits a thickness of about 10 to 20 μm and/or a length/width ratio in the range of about 20 to 60, preferably of about 40.

19. Detector as set forth in claim 17 or 18, characterized in that it is manufactured by a method as set forth in one of the claims 11 to 16.

20. Optoelectronic image-recording system, characterized by a focal surface (10; 50; 60) as set forth in one of the claims 1 to 8 and/or a detector (11) as set forth in one of the claims 17 to 19.

Abstract

A focal surface (10) for an optoelectronic image-recording system has an arrangement of detectors (11) for image recording and a detector carrier (15) or a FPA carrier for holding the detectors (11). The detectors (11) are each made of at least one silicon element that is bonded to a flexible carrier substrate (13). The focal surface or the detectors (11) exhibit a curvature, such that a curved field of view can be recorded. In a method for manufacturing a focal surface for optoelectronic image-recording systems, at least one silicon element is bonded to a flexible carrier substrate (13) to form flexible detectors (11), whereby a detector carrier (15) exhibits a curvature and the flexible detectors (11) are adapted to the curvature of the detector carrier (15). To manufacture a detector of the invention, a silicon element is thinned and bonded to a flexible carrier substrate (13), such that it is formed in a flexible manner and can be adapted to a curvature of a field of view. An optoelectronic image-recording system of the invention with front optics for capturing an image and a detector arrangement that is arranged in a focal surface of the front optics distinguishes itself in that the detector arrangement is arranged in the focal surface in a curved manner.

[Fig. 1]

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